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Investigating Li isotope composition of Nile deltaic sediments as paleotracer of continental alteration

Luc Bastian*[ab], Marie Revel [a], Nathalie Vigier [b]

a Nice Sophia Antipolis University, Observatoire de la Côte d'Azur, GeoAzur UMR 7329. Sophia Antilopis, France ,
b Laboratoire d'Océanographie de Villefranche. Villefranche sur Mer, France.

Abstract

We investigate the lithium isotope composition of the Nile-deep-sea fan sediments in order to document the effect of a rapid climate change (arid/humid transition) on continental chemical and physical erosion rates. δ^7Li values of silicate sediments vary between -1.4 and 2.8‰ for a period that range between 600 and 20600 cal years BP. During the arid/humid transition, δ^7Li values do not correlate with εNd(0) but with indices of alteration (e.g. Na/Ti), indicating the potential of this tool to trace past variations of continental silicate weathering.

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Keywords: Lithium isotopes; Climate; Alteration; Nile

1. Introduction

A few recent studies show that alteration of silicate phases at the watershed scale can respond to rapid climate change, and this may have an impact on the carbon cycle [1–3]. However, the control of alteration over short periods of time, the magnitude and the sense of its response remain debated. During the Pleistocene, arid and humid phases have alternated in the Nile fluvial basin in response of changes of the African monsoon intensity. The deep-sea-fan Nile sediments are sensitive archives of the corresponding landscape instability. They provide a unique opportunity to quantify the Nile river clastic discharge variations in relation with the African monsoon. Recent multi-proxy analyses performed on these sediments, over the last 25000 cal yrs BP, have shown large change in clastic sediment provenance [4]. The Nd and the Sr isotopic composition highlight a Blue Nile

* Corresponding author. Tel.: +33 (0)4 83 61 85 20; fax: +33 (0)4 83 61 85 01.
E-mail address: bastian@geoazur.unice.fr

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dominated signature during the humid period (14000 to 8000 cal yrs BP) and a Saharan Dust signature during the arid periods (LGM and the Late Holocene, 4000–2000 cal yrs BP). During early and mid-Holocene, high summer insolation enhanced the thermal contrast between land and sea. This produced strong summer monsoon which lead to the African Humid Period (AHP). At this period, the Equatorial lakes reached their highest level [5]. The actual Sahara desert was the site of green vegetation expansion and animal and human settlements. This humidification of the Sahara is the consequence of a remarkable transformation of the hydrological cycle in North Africa and is thought to be related to the intensification of the North African Monsoon favoured by the northward migration and/or the expansion of the Inter Tropical Convergence Zone (ITZC). However, the precise timing and amplitude of the arid/humid transitions is still not well constrained, neither its consequence on erosion and weathering conditions.

We propose to couple geochemical, isotopic and sedimentological approaches in order to study the relationship between climate, erosion and alteration during short periods of time (since the LGM) in the Nile Basin. In particular, we investigate the potential of Li isotopes measured in clay sediments exported by the Nile for tracing the impact of climate variations on continental alteration. Indeed, Li isotopes fractionate significantly during clay formation, resulting in elevated δ^7Li values in river and soil waters [6]. Most studies of Li isotopes in rivers and soils show that the areas which are characterized by low weathering rate display rather high δ^7Li values [7]. More recently, Li isotopes measured in river sediments deposited in alluvial terrace have shown to co-vary with climate proxies such as δ^{18}O [3]. This study highlights the potential of lithium isotopes as a paleotracer of continental alteration.

2. Methods

The Nile River, 6700 km length, is located in the eastern Sahara. The Nile watershed has an area of 3.000.000 million of km². It crosses 31° of latitude, from 4°S to 31°N, through a large variety of altitudinal, geological, geomorphological, climate and vegetation zones). The main Nile River is fed by two different fluvial systems, the White Nile and the Blue Nile/Atbara River. A large portion of the Nile basin is composed of Precambrian granitic and metamorphic rocks [8]. The Blue Nile/Atbara system drain the volcanic rocks trap from the Ethiopian Highlands [9] and Precambrian crystalline basement below. The White Nile drain in large part Precambrian granites, granulites and gneiss sequences. In southern Egypt and Northern Sudan the Nile drain clastic sequence et crystalline rocks [10].

We studied sediment core MS27PT, recovered during the Mediflux MINES oceanographic cruise in 2004. This core is located at less than 90km from the Rosetta mouth of the Nile (N31°47'90; E29°27'70) (Fig 1). The age of the sediments is based on 19 AMS ^{14}C measurements performed on planktonic foraminifera [4,11] and range from 500 to 20550 cal years BP. This time range, include two major climate transitions: the dry to wet LGM/AHP (14000 years) transition and the wet to dry AHP/Late Holocene transition (8000 years).

Both the <63µm size fraction sediments and <2 µm size fractions, were analyzed. Sediments were decarbonated with a 1N HCl

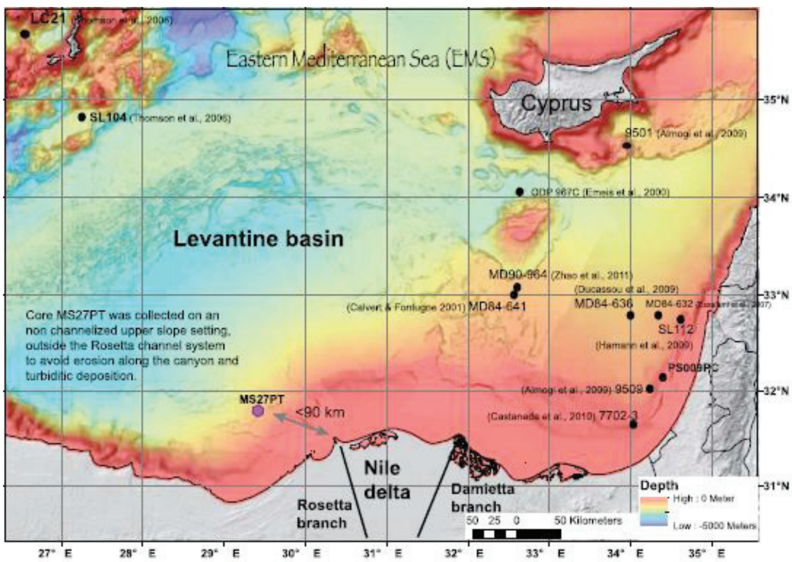

Fig 1 : Bathymetry map of the Nile delta and localization of the MS27PT core [4].

solution, rinse with water and dried at 65°C. The clay fraction was then collected after 6.5h using a solution of sodium-hexametaphosphate. The particle size of the clay fraction was measured and confirm the good clay separation. Li was separated using a modified technique from James and Palmer (2000). Li isotopes were measured using a Neptune *Plus* following the method described in [9]. The external reproducibility of the results is 0.3‰ at the 2σ level.

3. Results and Discussion

Li concentrations are relatively homogeneous, and range from 46 to 59 ppm in the silt silicate fraction. δ^7Li range between -1.4 and 2.8 ‰ in the same fraction, and between +1.8 and 2.5 ‰ in the clay fraction.

Preliminary results show that, at the Last Glacial Maximum/African Humid Period transition ε Nd(0) display a significant and rapid rise which reflects a rapid change of the source of the sediment [4]. This process is not associated with such rapid change of δ^7Li values, indicating that a change of source is not reflected by a significant change of sediment δ^7Li value. This is not surprising since it has been shown that this tracer is little sensitive to various lithological (silicate) sources,

In contrast, there is a co-variation between δ^7Li and εNd(0) during a flood event of the Nile highlighted at 8900 cal years BP by mud deposit. This can be explained by a rapid change of both physical and chemical erosion rates during this short period of time (<100 years). More investigation is now needed in order to complete and refine these paleo-variations at a higher resolution in time, and to better determine the influence of monsoon intensification on δ^7Li values and alteration rate In the Nile basin.

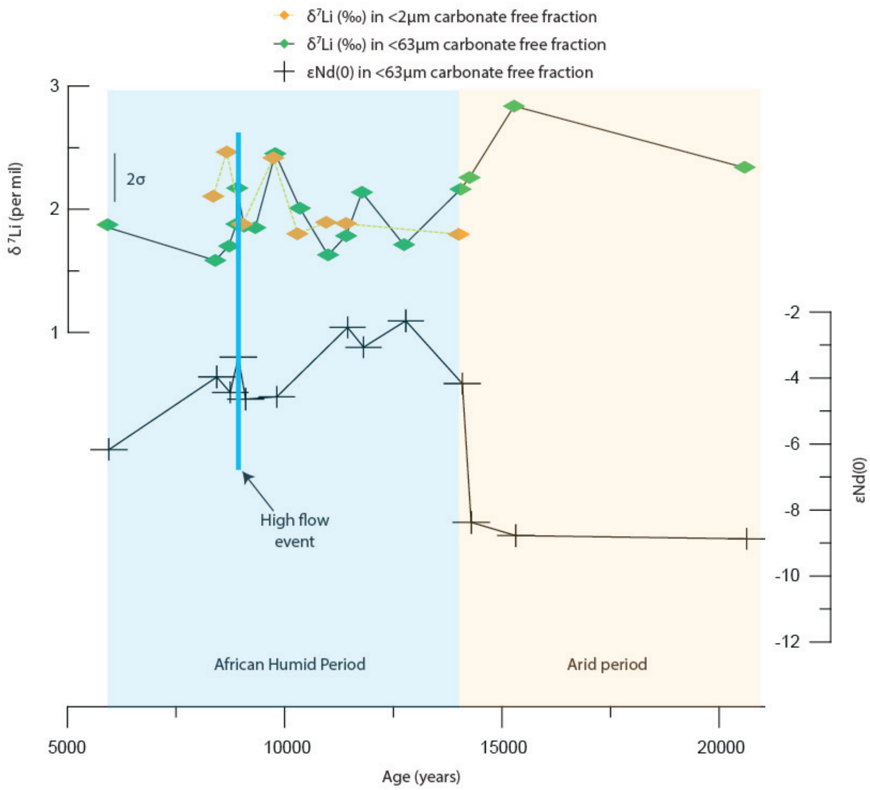

Fig 2: Plot of ε Nd (0) (black cross), δ^7Li on silt sediments (Green diamond) and in clay (Orange diamond).

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